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THE CHARACTERISTICS OF CURRENT AND RESISTANCE OF A LEAD-ACID BATTERY RECHARGER USING HIGH FREQUENCY PULSE

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ABSTRACT

This paper examines whether the difference exists when the only high frequency pulse is introduced to a lead-acid battery charger, and when continuously charged with ordinary charger. Intend to designed to charger when input to AC power, circuit design changing to general trend what charger size is smaller and efficiency of charger to the max, PFC, Fly-back converter, switching technology of passive element make the best use of technology. Lead-acid battery inner part are checked to find if it is in normal state or dangerous state through SOC method. To make a decision state of battery that in the PbO_2, in the over charging, in the over discharger as from protected to battery Lead sulfate is generated in the lead-acid battery if it undergoes repeated charging and discharging. Increase in the quantity of lead sulfate will reduce chemical reaction within the lead-acid battery, along with an increase in internal resistance to lower the voltage of the battery, thereby resulting in degradation of the lifespan and performance of the battery. The current of the lead-acid battery recharger manufactured will be measured for comparison prior to and after the input of high frequency pulse. High frequency pulses will be generated with a frequency of approximately 70 kHz and inputted into the lead-acid battery, which will then be discharged. Then the change in current and recharging times will be compared with those of ordinary rechargers to present the effects of high frequency pulses on lead-acid batteries.

KEYWORDS: High Frequency, Pulse, Lead Dioxide (PbO_2), Charger & Current

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Original Article

1. INTRODUCTION

Batteries supply electric power in the form of direct current. The device that require electric power. It is supplied by converting chemical energy into electric energy. Depending on the types of this chemical energy, not only the types of the battery, but also the output voltage of the battery differ along with completely different areas and subjects of application of the battery. Therefore, types, characteristics, and applications of batteries differ depending on the chemical energy. The battery type which is dealt with in this paper is the lead-acid battery that is used widely in starting automobiles, golf carts, forklifts, and some ESS, etc. Characteristics of the lead-acid battery would be examined.

The means of recycling waste batteries for which their uses are directed in automobiles and various other areas, and also utilizing batteries by extracting rare metals through chemical decomposition for reusing them in other areas are being introduced. [1] If lead-acid batteries are repeatedly charged and discharged for prolonged periods of time, crystallization occurs at the electrode plate at the time of discharging, which would increase internal resistance. Furthermore, if sulfate accumulates at the electrode plate due to extensive corrosion or

crystallization, the battery needs to be disposed off, even if there is more than 2~30% residual power remains in the battery. However, it is possible to regenerate the battery by removing the crystallized sulfate with a high-frequency pulse only when little residual power within the lead-acid battery [2].

This paper will examine the effects of the removal of sulfate and the characteristics of restoring the efficiency and performances of lead-acid batteries by using high frequency pulses on the recharging time, and will deduce the results on whether there are difference in recharging times in comparison to those garnered by using ordinary rechargers.

2. LITERATURE REVIEW

Battery preserves the chemical energy and then the battery offers power when needed. Load size depending on chemical energy change to electric energy as trust of battery very important that using to ESS, UPS, ETC makes the use of safety power output and emergency power product. In addition, state of battery must be always checked, if it is on the normal state or dangerous state. However, in lead-acid battery inner part cannot be checked by human therefore other method are used to check the battery [3]. Lead-acid battery be based on charging/discharging, on around of the environment(temperature), on charging voltage get out of safety range, on lacking an electrolyte level, etc, does corroded by increase to sulfuric acid solution therefore cycle of Lead-acid battery will be decrease result. Thus must to check to SOC prevent to state of affairs statue of a battery.

2.1 Characteristic of Lead-Acid Battery

Battery with inner part $PbSO_4$, when charging/discharging of Lead-acid battery, if any don't erase to pbso4 using two batteries, efficiency and life cycle of lead-acid battery would be lowered, because of which the lead-acid batteries use would not be possible. Figure1 shows the Schematic illustration of lead-acid battery, chemical reaction shows the positive poles PbO_2 with negative poles Pb responding to sulfuric acid ion to make $PbSO_4$ and water (H2O). This reaction changes the chemical energy to electric energy as expressed in equation (1).

(Reaction at the cathode of a lead-acid battery)

$$\mathrm{Pb}O_2 + 3H^+ + HSO_4^- + 2e^- \underset{charge}{\overset{Discharge}{\Longleftrightarrow}} PbSO_4 + 2H_2O \tag{1}$$

(Reaction at the anode of a lead-acid battery))

$$\mathrm{Pb} + \mathrm{HS}O_4^- \underset{charge}{\overset{Discharge}{\Longleftrightarrow}} PbSO_4 + H^+ + 2e^-$$

(Reaction in a whole lead-acid battery)

$$\mathrm{Pb}O_2 + Pb + 2H_2SO_4 \underset{charge}{\overset{Discharge}{\Longleftrightarrow}} 2PbSO_4 + 2H_2O \tag{2}$$

In addition, it returns to the original state where it would be capable of discharging through a charging reaction where $PbSO_4$ with water (H2O) are decomposed and reduced to PbO2 and Pb (equation 2). This chemical reaction occurs continuously, that $PbSO_4$continuouslygrows in the batteries internal part. However, the activity of electron will be slower which would lower the performance; hence performance of lead-acid battery is lowered [4][5].

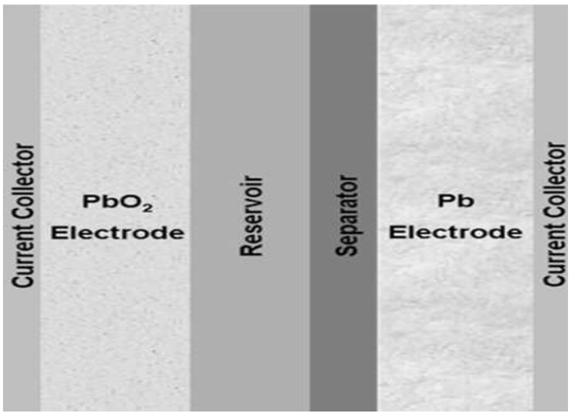

Figure 1: Schematic illustration of Lead-Acid Battery

2.2 SOC Deduction

In order to maintain the original performance of the lead-acid battery, it is necessary to check and manage the lead-acid battery modeling for good efficiency. Both charging and discharging are not good for the battery, and the battery is consumed quickly within a short period. In order to prevent this, the state of the lead-acid battery should be checked through the SOC. There are several methods of SOC, but there are cases where SOC is distorted by noise. Therefore, the SOC estimation method with the least effect of disturbance is introduced, and the characteristics are different for each SOC estimation method.

- **Hydrometer Method**

It is possible to accurately express the capacity of the remaining battery which is the remaining capacity in the state where the lead accumulator is stabilized. However, if the load is not constant and fluctuates, this method cannot be applied.

- **Open-Circuit Voltage Measurement**

The remaining amount of the lead accumulator battery can be inferred by using the output voltage of the battery. However, the voltage stabilization time is required and cannot be used if the load is fluctuating.

- **Accumulation Ammeter Method**

If the capacity of the initial battery is not known or the wrong capacity is detected, it is impossible to see a proper SOC because the initial capacity is estimated based on the information of the battery. Also, as errors accumulate, errors occur as time passes[6].

- **OCV: Open Circuit Voltage**

Refers to the terminal voltage measured in the absence of charge / discharge current in the cell, and refers to the value measured about one hour after the charge / discharge current is applied. The OCV should appear linear relative to the energy value charged to the nominal capacity, but it often appears non-linear depending on the internal structure of the lead-acid battery and the additive material.

- **Peukert Equation**

The SOC is estimated using the equivalent circuit model shown in Figure 2, of the battery such as the capacity and discharge current of the battery. If the discharge current fluctuates, it may be difficult to follow the SOC due to the limitation of accuracy.

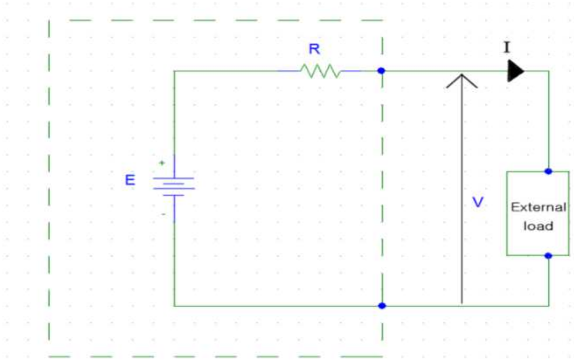

Figure 2: Battery Equivalent Circuit Model

$$C_a = \frac{K}{{I_d}^{(n-1)}} \tag{3}$$

The expression of Peukert Equation is expressed by Equation (3). n and K are constants depending on the temperature, concentration, and battery structure of the electrolyte, and n and K are constants.

In addition, the method of Peukert Equation and by substituting the temperature in Eq. (3) can be expressed as Eq. (4). It is physically unreasonable when $I_d \rightarrow 0, Ca \rightarrow \infty$, so that SOC can be estimated only by a constant discharge current. Therefore, it can't be used if the magnitude of the current changes greatly[7][8].

$$C_a = \frac{K(1+at)}{{I_d}^{(n-1)}} \tag{4}$$

- **SOC Estimation using Kalman Filter**

If Kalman filter is used, SOC estimation can be realized in real time and it shows strong characteristic of disturbance. However, as the nonlinear characteristics of the battery have a disadvantage that the calculation time increases as the number of state variables increases, now it seems to be a good way to estimate the accurate SOC by increasing the calculation speed of the computer. The most important information here is OCV (Open Circuit Voltage). Fig.3 shows a graph similar to the hysteresis characteristic of OCV.

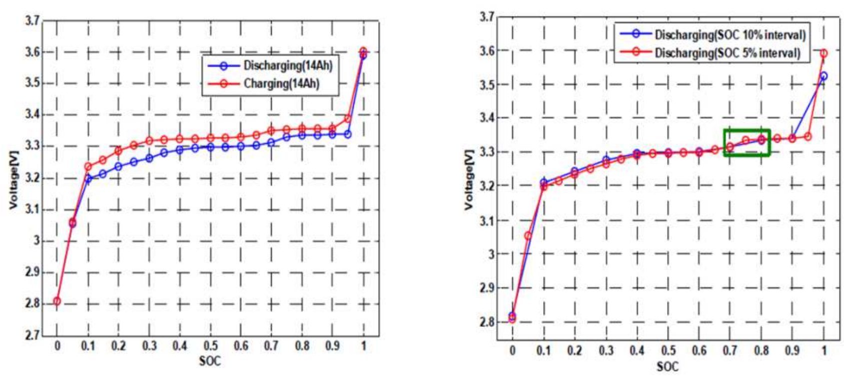

Figure 3: OCV Hysteresis Characteristics Graph [9]

If the soc is not correct, abnormal discharging of the battery may occur. And it is necessary to verify it because it depends on environment including SOC size, charge / discharge mode, hysteresis, and temperature and humidity[10].

2.3 A Type of Lead-Acid Battery Charger

Efforts are being made to reduce energy consumption, power consumption, making them eco-friendly and economically cheap. Research is underway to improve efficiency and performance. Increasing efficiency is a way to reduce losses. Reducing losses and reducing power factor are ways to prevent energy wastage. The place where the most energy loss is consumed is a transformer that converts the power, and it releases energy to heat, resulting to a lot of energy loss. One way to improve this is to reduce the loss by changing the shape of the winding. Experiments and studies that improve efficiency and coupling while compensating for existing transient drawbacks will help prevent loss of transformers.

2.4 LLC Charger using a Converter

The LLC resonant converter is designed to maintain the efficiency of the LLC converter while maintaining the soft switching conditions even under load. The converter uses two transformers to make the ratio of resonant inductance to magnetizing inductance less than one to minimize frequency fluctuations. This will increase the size, but use two transformers to prevent volume, but the space will increase. However, the frequency fluctuation width can be minimized according to the variation of the input voltage. However, I do not think it is a good idea to use the two without the complexity of the circuit or the device to support it. Improving existing transformers will be good for efficiency and performance.

2.5 High Frequency Pulse Charger

In order to charge the battery and make the frequency, DC voltage must be input, but DC voltage must also be converted from AC power to make DC voltage. Therefore, it is demanding to miniaturize AC / DC adapter with technical requirement such as high efficiency and standby power cut-off. The power supply circuit of the existing AC / DC is occupied by the passive element and it is affected by the volume of the passive element. However, by increasing the switching frequency, it is possible to reduce the volume of the passive element and make it possible to miniaturize. And a hardware switching method and a PWM converter switching method can be utilized through a resonant capacitor and an inverter. However, as the switching frequency increases, the switching loss also increases proportionally. Therefore, when the frequency is increased beyond a certain frequency, heat generation and efficiency decrease due to loss, which makes it difficult to drive. To improve the problem, a PFC circuit can be added or a converter can be added to compensate [11]. Therefore, the high-frequency pulse will be applied after making the pulse using the LM741 or 555Timer IC chipset. VCC and VEE to be input to this chipset will make the AC / DC power supply circuit composed of the Fly-back converter, Make the difference clear.

As a result of the high-frequency pulses as described above, it is possible to reduce the internal resistance of the lead-acid battery by inputting a high-frequency pulse having a long period of time and a high efficiency and confirming the reduction reaction with Pb and PbO_2, We will check life extension.

3. EXPERIMENTAL SETUP

3.1 Structure of Lead Acid Battery

Lead-acid batteries utilizes the voltage generated through reactions between lead dioxide and the lead of cathode poles with sulfuric ion. Sulfate generated as by-product at the time of discharging is accumulated at the plate and separator. If a large quantity of sulfate is accumulated due to repeated charging and discharging, the chemical reaction is reduced with an increase in internal resistance, which will lead to a shortening of the lifespan, or an inability to use the battery any longer due to a drop in the voltage generated within the battery[12].

Figure 4 illustrates the structure of a lead-acid battery composed of plates and separator. If a lead-acid battery is recharged with a recharger that uses high frequency pulses in order to remove sulfate accumulated on the plates and separator, the pulses disintegrate the accumulated sulfates into sulfuric ion to reduce interfering ions and internal resistance in comparison to of the conditions under the state of accumulated sulfate. Observations will be made on whether the recharging time is reduced due to an increase in current in comparison to that when the sulfate is present.

3.2 Experimental Condition

With a 12V 80Ah lead-acid battery, discharge the voltage of the battery to 12V, and recharge it to 13V repeatedly. High frequency pulses are inputted with an output of 70 kHz and 14.2V by utilizing a 555 Timer IC as illustrated in Figure 5 of the experiment. Ordinary charger with outputs of 15V are used for comparison purposes.

Charging and discharging was executed repeatedly. At that time, recharging was executed only with rechargers with ordinary outputs of 15V. After having executed repeated recharging and discharging processes several times, high frequency pulses were applied to the terminal to check whether sulfate was removed via application of the pulse.

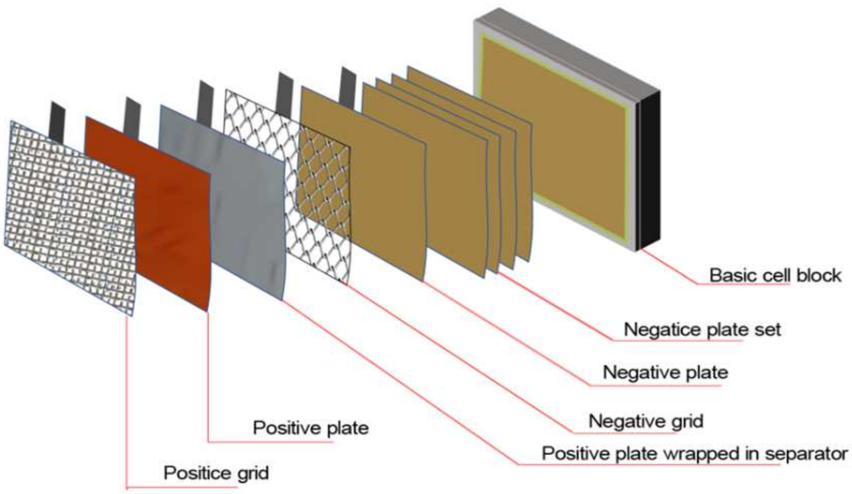

Figure 4: Lead – Acid Battery Structure

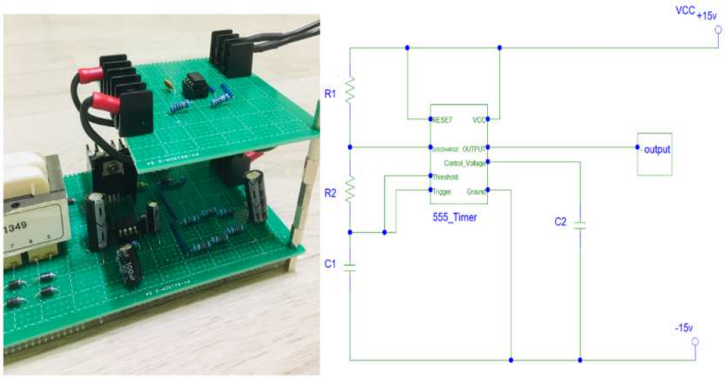

Figure 5: High Frequency Pulse using 555 Timer Circuit

4. RESULTS

15V was used, and current during charging was marked by using an ammeter. The current and voltage between the terminals of the ordinary charger with output value approximately 1.5A, and 15V &power output of 22W. Internal resistance of the lead-acid battery was computed to be approximately 11.5Ω in accordance with Ohm's Law. After having applied high frequency pulses of approximately 70 KHz following the charging and discharging process several times, the battery is charged with ordinary charger. This resulted in an increase in the currency output of approximately 1.8A and overall power output to 27W. It can also be confirmed that there is approximately a 28% reduction in the internal resistance of the lead-acid battery to approximately 8.3Ω in Figure 6.

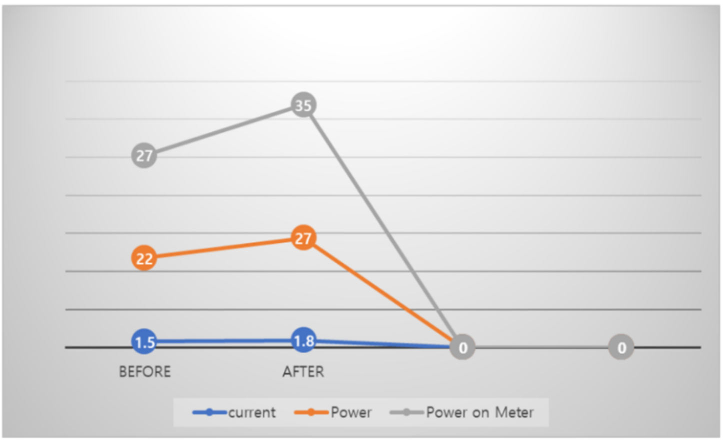

Figure 6: Relationship Prior to and following the Pulse Recharging

Sulfate, which is an ion layer, is generated due to repeated charging and discharging, and it interferes with recharging. When the pulse waveform is inputted before recharging the battery with a recharger, it can be seen that the output power and current increase in comparison with those prior to applications of the pulse waveform. Accordingly, it can be confirmed that sulfate is reduced by the high frequency pulse [13-14].

5. CONCLUSIONS

Sulfate accumulates in lead-acid batteries used in a wide range of areas, due to internal chemical reactions as the recharging and discharging process is repeated. It was possible to indirectly confirm that the accumulated sulfate is disintegrated again through application of pulse waveforms [14].

Although rapid recharging can be executed with high current and voltage, if it is executed repetitively, then sulfate will be accumulated inside the lead-acid battery, which will increase the internal resistance and lower the voltage between the terminals, thereby degrading the lifespan and performance of the battery. In this thesis, it was confirmed that there exists internal change in the lead-acid battery due to high frequency pulses while recharging the battery with low output power and current. Therefore, this thesis presented the means of shortening the recharging time, while simultaneously extending the lifespan and lowering the required maintenance of the initial performances of the lead-acid battery by removing sulfate accumulated in the battery through application of high frequency pulses to lead-acid battery recharger.

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